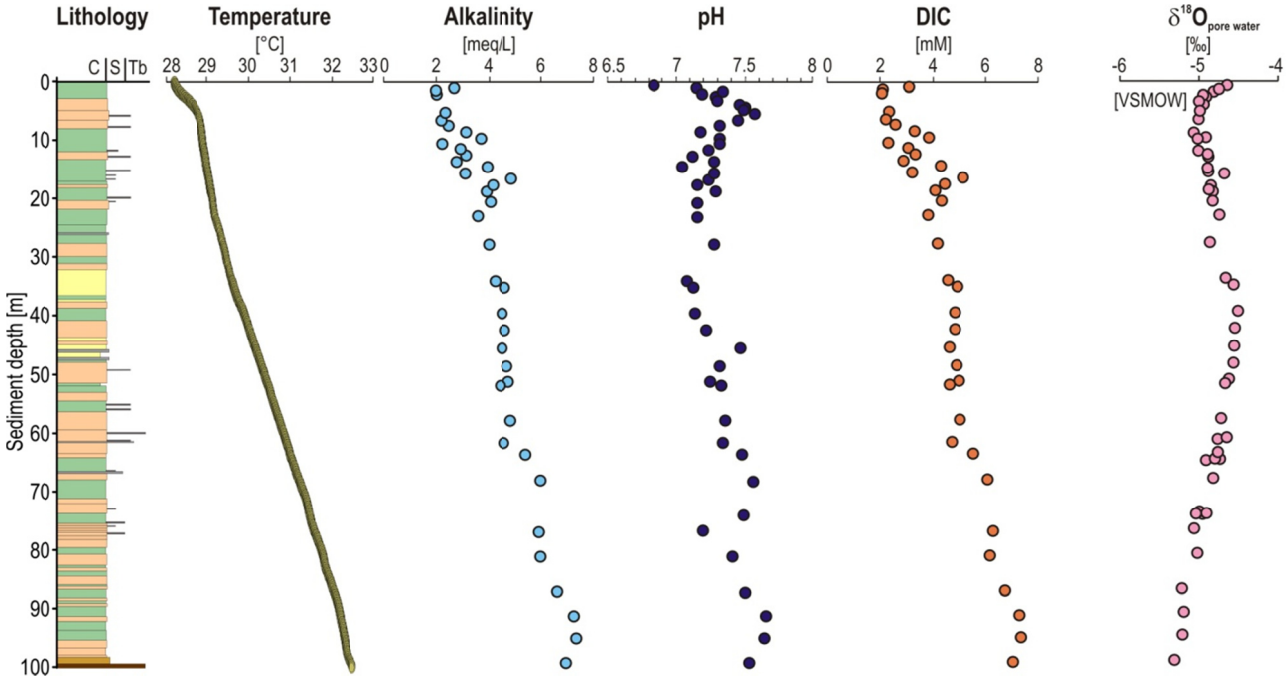
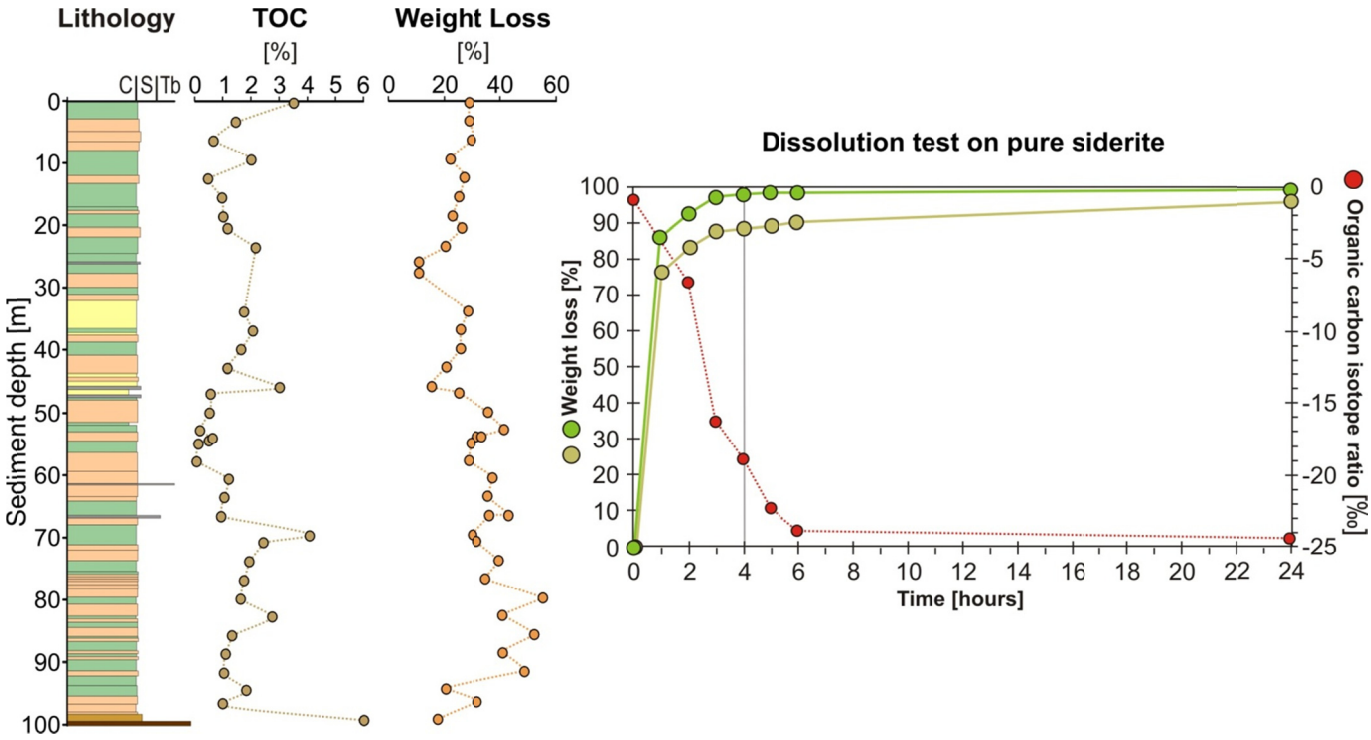
Vuillemin, A., Mayr, C., Schuessler, J.A., Friese, A., Bauer, K.W., Lücke, A., Heuer, V.B., G, C.lombitza, Henny, C., von Blanckenburg, F., Russell, J.M., Bijaksana¸ S., Vogel, H., Crowe, S.A., and Kallmeyer, J., 2022, A one-million-year isotope record from siderites formed in modern ferruginous sediments: GSA Bulletin, https://doi.org/10.1130/B36211.1.

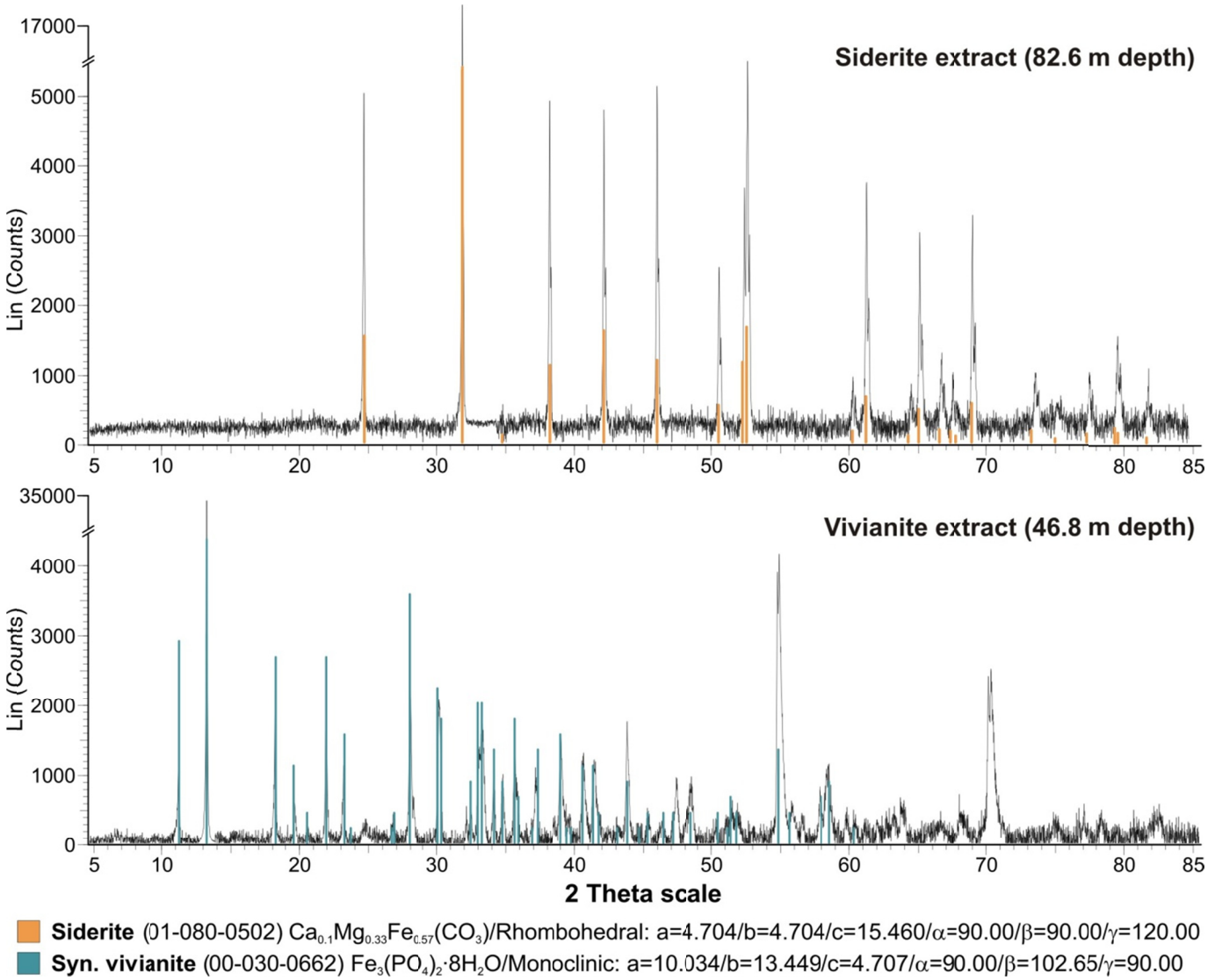
Supplemental Material



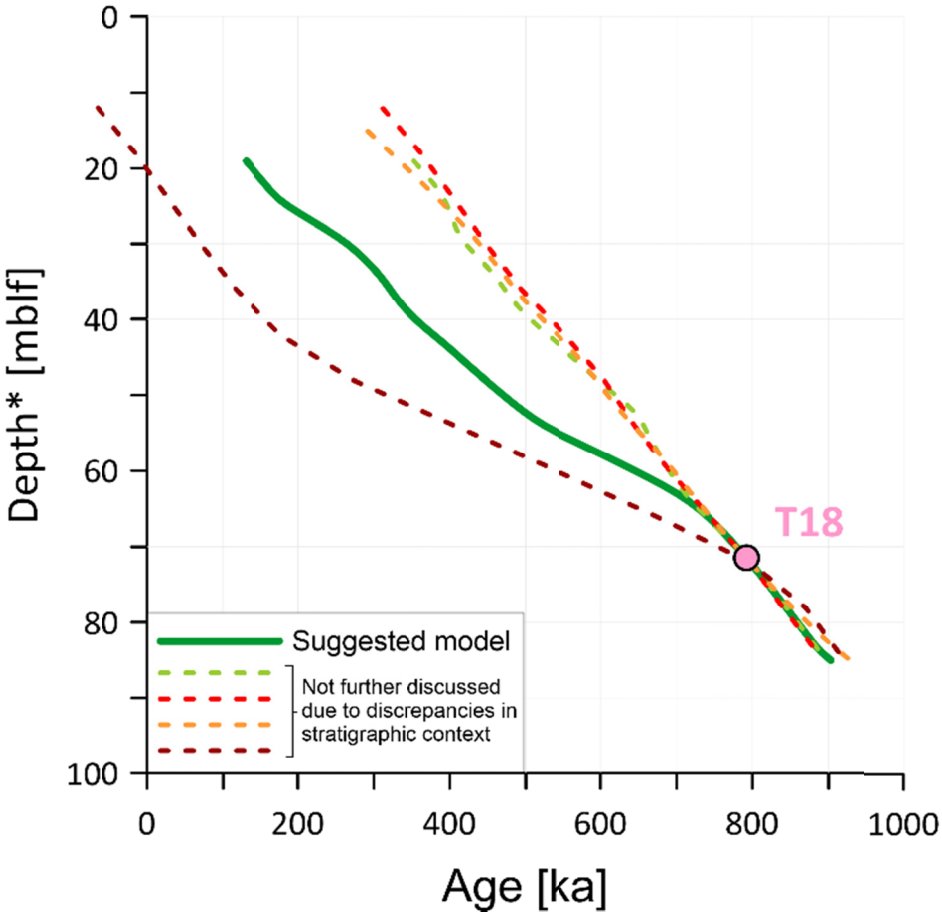
Supplementary Figure S1. Down core profiles for physicochemical parameters and pore water oxygen isotopes. From left to right: Borehole temperatures obtained on site via borehole logging, showing an overall increase in temperatures from 28° to 33° C in the 100 m of Unit 1 at hole TDP-1B; alkalinity [meq × L^{-1}], and pH measured on pore water at hole TDP-1A; DIC calculated by solving the carbonate system based on the previous two profiles; oxygen isotopes versus VSMOW [‰] in the pore water display little variations despite a temperature increase of 4°C.



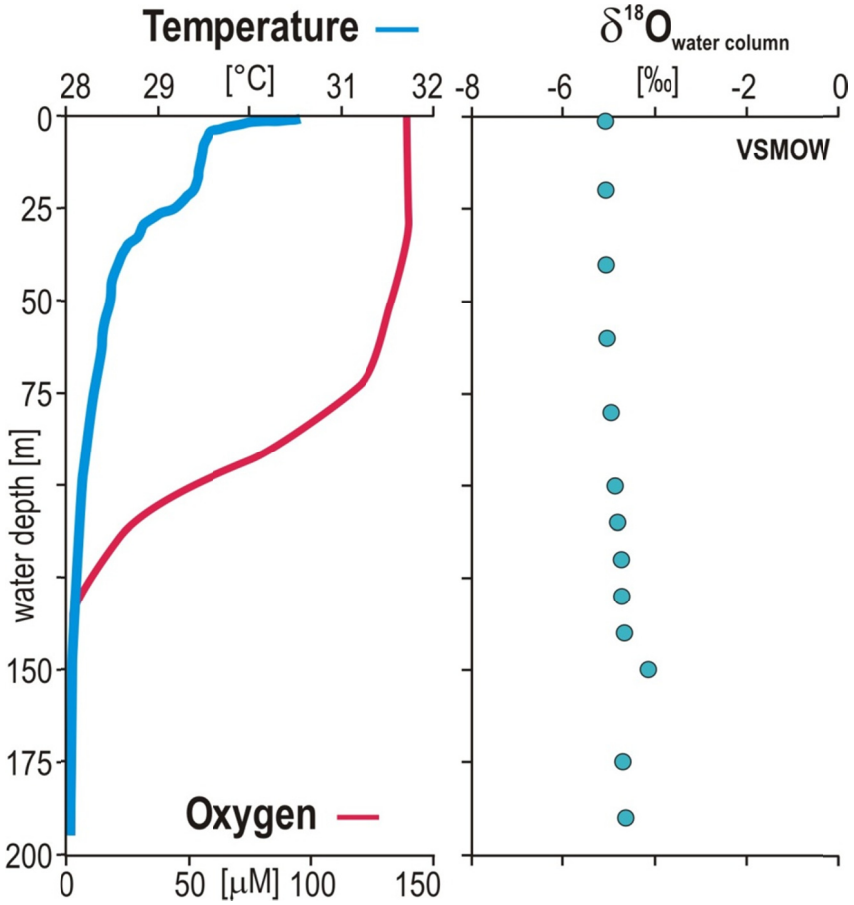
Supplementary Figure S2. Treatment of bulk sediments and siderite for carbonate dissolution. Bulk sediment samples were treated with 20 mL of 5 % HCl at 50° C for 24 hours to remove carbonates. This treatment was tested with 200 mg of technical grade siderite to evaluate its dissolution over time. Results show that 85 to 95 % of the siderite weight is dissolved after 2 hours. After 24 hours, >95% of siderite is dissolved, ensuring accurate measurement of both total organic carbon content and $\delta^{13}C_{org}$ composition on bulk sediment.



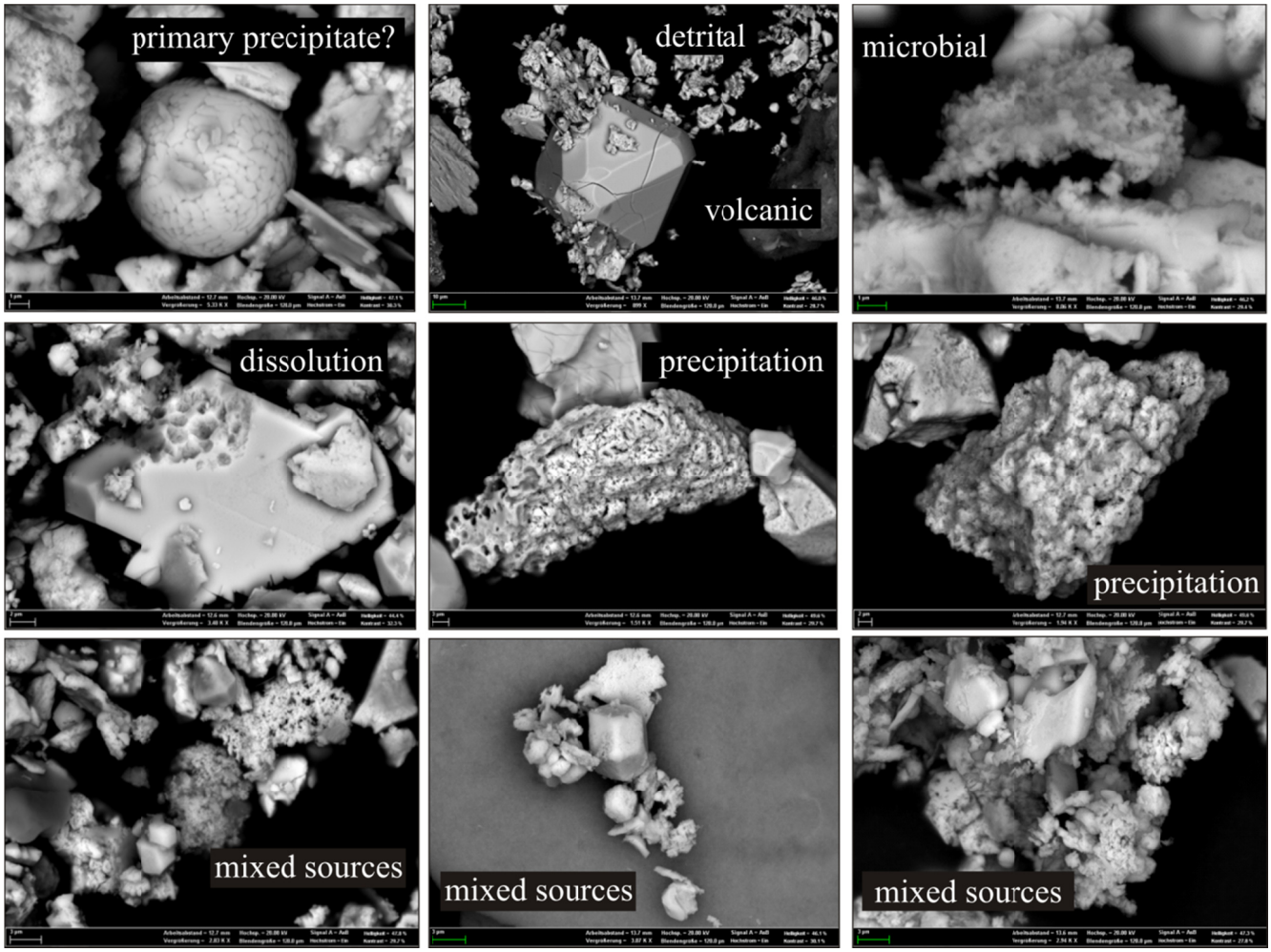
Supplementary Figure S3. XRD spectra for siderite and vivianite extracts. XRD spectra of pure siderite (top) and vivianite (bottom) extracts from 86.2 and 46.8 m depth (modified from Vuillemin et al., 2019a, 2020), respectively, with reference peaks of synthetic siderite (orange bars) and vivianite (blue bars).



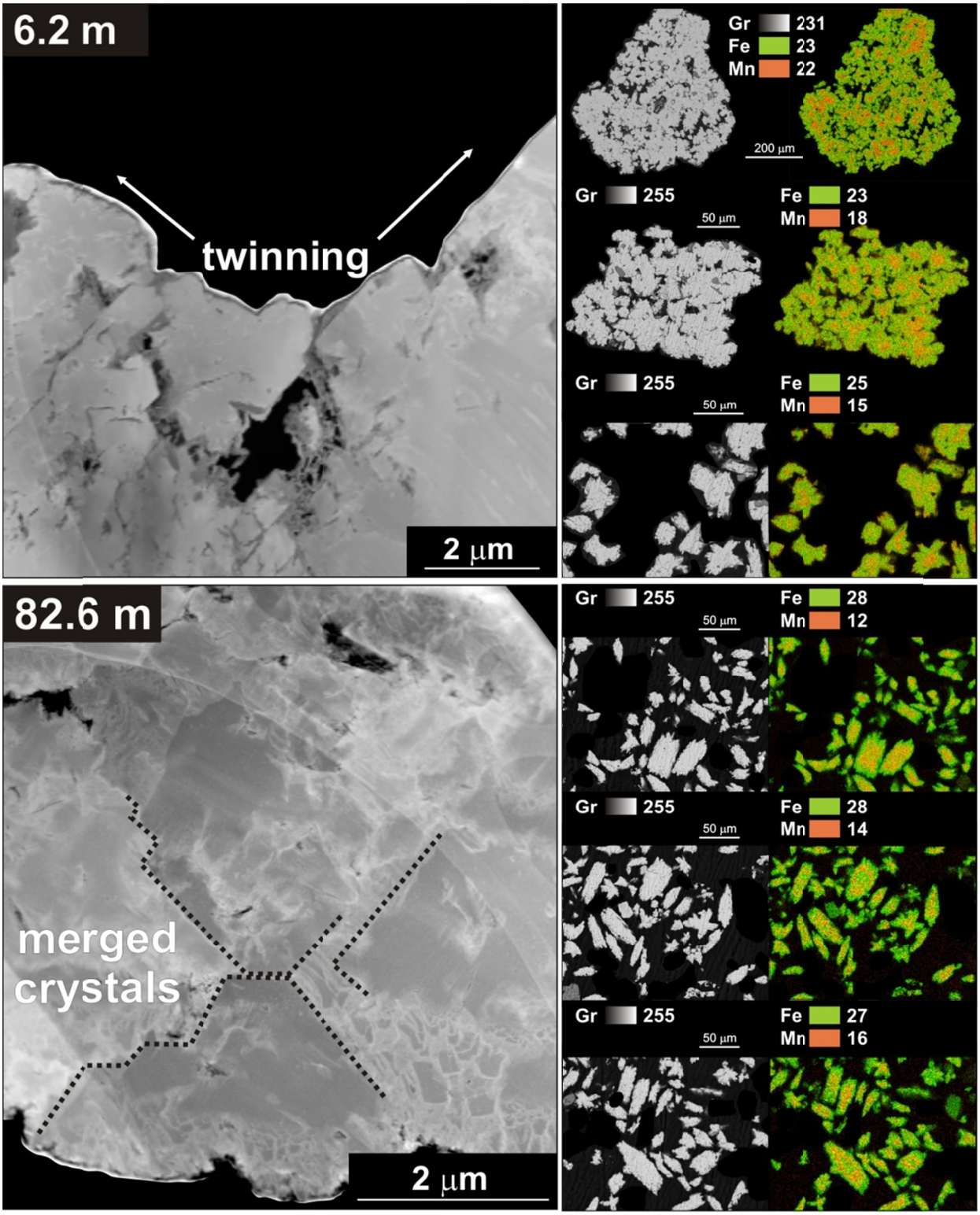
Supplementary Figure S4. Age-depth models from Lake Towuti Unit 1. This figure (from Ulfers et al., 2021) displays the age-depth models for the lacustrine sequence (i.e. Unit 1). The upper part was constrained by 20 AMS ^{14}C ages measured on terrestrial macroremains (Russell et al., 2014). All models are tied to the dated tephra T18 (pink dot) from Russell et al. (2020) at 72.95 mblf.



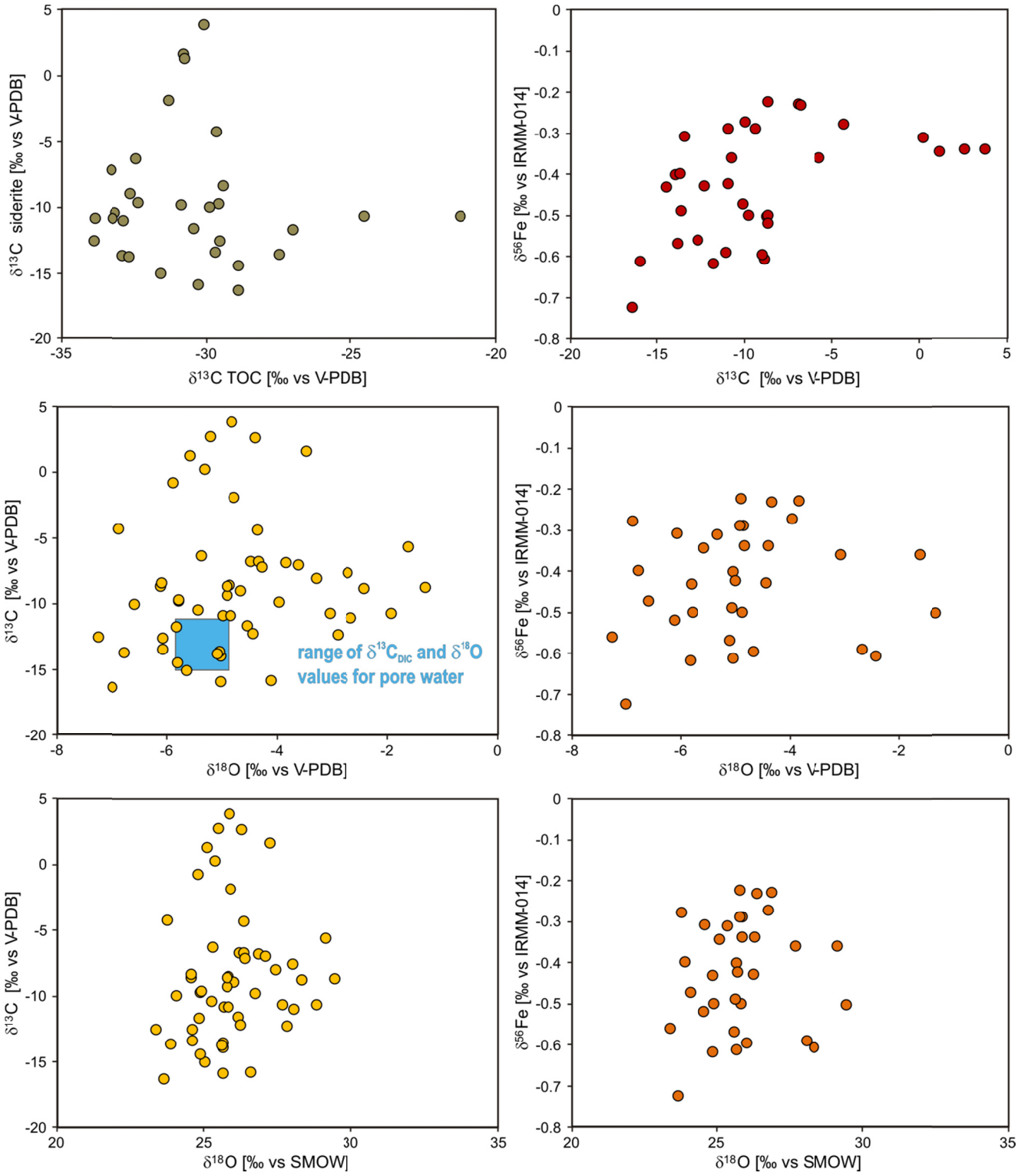
Supplementary Figure S5. Temperature, oxygen concentrations and isotopes in the water column. (Left) Down cast of temperature [°C] and oxygen concentration [µM] measured in the water column (from Vuillemin et al., 2016). (Right) $\delta^{18}O$ values [‰] relative to VSMOW for water column samples, which remain fairly constant throughout the water column despite a temperature decrease of 2.5°C (see Fig. 4B).



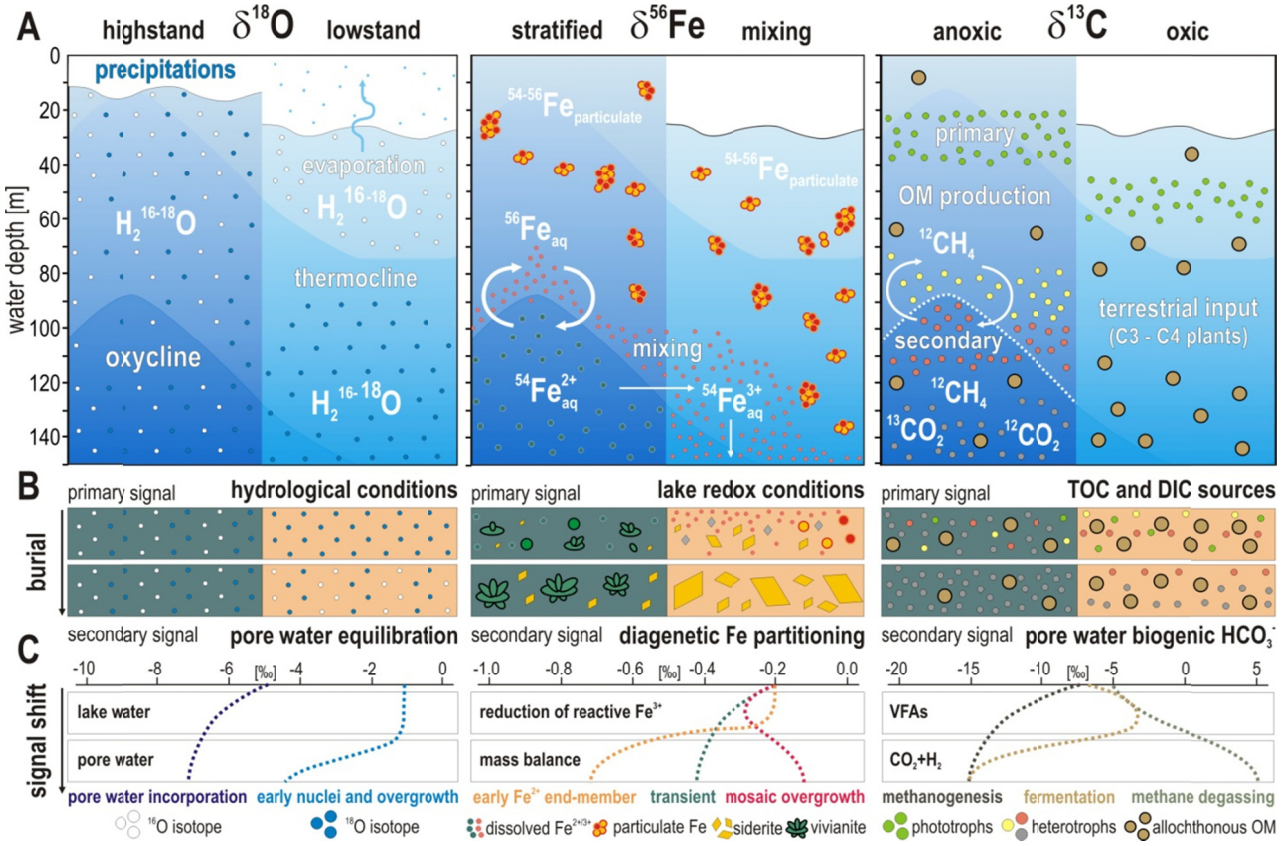
Supplementary Figure S6. SEM back-scatter images of magnetite extracts illustrating their multiple sources. The upper left picture (sediment sample: 0.7 m depth) shows a magnetite framboid which could be a primary precipitate from the water column. The origin of magnetite crystals e.g. detrital, volcanic, microbially precipitated are often found as a mixture making hard to discriminate microbially-mediated phases. Nevertheless, features of reductive dissolution and (re)precipitation are commonly observed (modified from Vuillemin et al., 2019a).



Supplementary Figure S7. Transmission and scanning electron microscopy imaging of siderites with elemental mapping of nuclei and rims. (Left) Scanning TEM images of siderite crystals from 6.2 and 82.6 m sediment depth, showing that crystal development through twinning and coalescence into mosaic aggregates. (Right) SEM back-scatter electron images with EDS elemental mapping of thin sections prepared with siderite separates from 6.2 and 82.6 m sediment depth. Stacked intensity images for Fe + Mn indicate that Fe substitution by Mn occurs preferentially in the center of siderite crystals and thereby evidence the presence of nuclei within crystal aggregates (modified from Vuillemin et al., 2019a).



Supplementary Figure S8. Scatter plots of siderite isotope compositions. (Top) Carbon isotope composition ($\delta^{13}C$ in‰ relative to V-PDB) of TOC versus siderite (left); carbon isotope composition ($\delta^{13}C$ in‰ relative to V-PDB) versus iron isotope composition ($\delta^{56}Fe$ in‰ relative to IRMM-014) measured on siderites. (Middle) Oxygen isotope composition [‰] relative to V-PDB versus carbon (left) isotope composition [‰] relative to V-PDB, and (right) Fe isotope composition [‰] relative to IRMM-014 measured on siderites. (Bottom) Same scatter plots with $\delta^{18}O$ values [‰] relative to VSMOW.



Supplementary Figure S9. Syn-depositional and post-depositional processes setting the $\delta^{18}O$, $\delta^{56}Fe$ and $\delta^{13}C$ signatures in siderites. (A) Lacustrine conditions, from left to right: ^{18}O composition related to lake level highstand (left) and lowstand (right); sources of detrital and authigenic ferric phases under stratified (left), mixing (center) and oxic conditions in the water column; processes of organic matter production and remineralization in the water column under stratified (left) and mixing (right) conditions. (B) Evolution of sediment composition during shallow (primary signal) to deep (secondary signal) burial, from left to right: Isotopic equilibration from bottom waters initially reflecting hydrological conditions to pore water composition; dissolution of Fe precipitates reflecting the lake redox conditions and partitioning of dissolved Fe^{2+} into diagenetic phases such as vivianite and siderite; remineralization of organic sources through anaerobic processes to methanogenesis wleading to biogenic production of DIC but little degradation of terrestrial organic sources. (C) General trends in isotope signals expected from the incorporation of pore water H_2O, dissolved Fe^{2+} and biogenic HCO_3^- in siderite in surface (upper case) and deep sediment (lower case), from left to right: Overgrowth on initial siderite nuclei; reductive dissolution of Fe phases; and rates of OM remineralization. Continuous mineral precipitation from saturated pore water leads to a mass balance effect over time.

Supplementary Table S1. Oxygen isotope fractionation factors between different phases and siderite.

Reference	Phases	Temperature	Fractionation factor (α)
Rosenbaum & Sheppard, 1986	CO_2 - siderite	25°C	1.01163
		50°C	not measured
Equation used:		**70°C**	**1.009706**
$10^3 \ln \alpha = 6.84 \times 10^5 (1/T^2) + 3.85$		100°C	1.00881
		150°C	1.00771
Carothers et al., 1991	CO_2 - siderite (phosphoric acid)	natural 25°C	1.01165
		synthetic 25°C	1.01175
		natural 50°C	1.01079
		synthetic 50°C	1.01075
Pore water to siderite	H_2O - siderite	**33°C**	**1.03033**
Factor used: 1.03033		56°C	1.02640
T° range in Towuti: 28 to 33°C		103°C	1.01893
		150°C	1.01322
		197°C	1.01067
	H_2O - calcite	102°C	1.01750
		102°C	1.01740
Swart et al., 1991	CO_2 - calcite (phosphoric acid)	LMC acid bath	
		89.9°C	1.00798
		81.0°C	1.00816
		70.6°C	1.00837
		59.7°C	1.00875
		50.9°C	1.00898
		25.0°C	1.00989
		sealed vessel	
		90.0°C	1.00821
		75.0°C	1.00853
		50.0°C	1.00924
		35.0°C	1.00982
		25.0°C	1.01025
		PSU acid bath	
		89.9°C	1.00799
		81.0°C	1.00823
		70.6°C	1.00831
		59.7°C	1.00871
		50.9°C	1.00904
		25.0°C	1.00989
		sealed vessel	
		89.9°C	1.00827
		81.0°C	1.00854
		70.6°C	1.00929
		59.7°C	1.00961
		50.9°C	1.01000
		25.0°C	1.01025
Mortimer & Coleman, 1997	H_2O - siderite	Fe pure 30°C	1.0203
		Fe pure 30°C	1.0224
		Fe pure 30°C	1.0257
		Fe pure 30°C	1.0245
		Fe pure 30°C	1.0251
		Fe pure 30°C	1.0275
		Fe pure 30°C	1.0297
		Fe pure 30°C	1.0261

		Fe pure 35°C Fe pure 25°C Fe pure 35°C Fe pure 40°C Mg/Ca 25°C Mg/Ca 30°C Mg/Ca 35°C Mg/Ca 35°C Mn 25°C Mn 30°C Mn 35°C Mn 35°C Mn 18°C Mn 25°C Mn 30°C Mn 35°C Mn 35°C Mn 40°C	1.0258 1.0266 1.0232 1.0239 1.0278 1.0264 1.0263 1.0241 1.0220 1.0238 1.0232 1.0237 1.0220 1.0236 1.0235 1.0234 1.0226 1.0221
Fernandez et al., 2016	CO_2 - siderite	sealed vessel **70°C** open vessel 100°C	 **1.01014 ± 0.0002** 1.00983 ± 0.0002

Supplementary Table S2. Results of iron isotope analyses on siderite samples and reference materials for data quality control. Measurement accuracy and precision was assessed by repeated analyses of pure Fe standard solution (HanFe) in each analytical session. This standard gave ^{56}Fe of 0.31 ± 0.02 (2 s, n=10), identical to results obtained in an inter-laboratory comparison. The procedure was also tested by processing the reference materials COQ-1 and BHVO-2 repeatedly through the same chromatographic separation protocol as the samples, with and without HCl or acetic acid treatment. This method yielded ^{56}Fe values for COQ-1 of -0.04 ± 0.04 (2 σ, n=4), -0.02 ± 0.04 (2 σ, n=4), -0.05 ± 0.04 (2 σ, n=2), and for BHVO-2 -0.12 ± 0.01 (2 σ, n=2), which are in agreement with published results. In addition, a pure siderite mineral powder was used to test the acetic acid leaching method. The ^{56}Fe results of siderite leached with 10 % acetic acid (-0.37‰) are identical to the reference value obtained by complete dissolution of the same siderite powder in 6M HCl (-0.35‰).

sample	dissolution procedure	δ^{56}Fe	depth (mblf)
siderite			
1H1	10 % acetic acid, 24h	-0.23	0.2
3H3	10 % acetic acid, 24h	-0.36	6.2
5H3	10 % acetic acid, 24h	-0.50	12.4
15A3	10 % acetic acid, 24h	-0.40	36.7
29H3	10 % acetic acid, 24h	-0.43	36.7
34H3	10 % acetic acid, 24h	-0.29	76.7
36H3	10 % acetic acid, 24h	-0.25	82.6
36H3	10 % acetic acid, 24h replicate[a]	-0.22	82.6
37H3	10 % acetic acid, 24h	-0.28	85.6
38H3	10 % acetic acid, 24h	-0.31	88.6
39H3	10 % acetic acid, 24h	-0.34	91.6
41H3	10 % acetic acid, 24h	-0.34	96.4
48H3	10 % acetic acid, 24h	-0.28	113.6
4H2	10 % acetic acid, 24h	-0.50	7.1
4H4	10 % acetic acid, 24h	-0.61	8.8
7H6	10 % acetic acid, 24h	-0.31	18.0
9H2A	10 % acetic acid, 24h	-0.52	21.2
9H3	10 % acetic acid, 24h	-0.47	21.8
17H1	10 % acetic acid, 24h	-0.59	41.1
18H1	10 % acetic acid, 24h	-0.56	43.0
22H3	10 % acetic acid, 24h	-0.62	49.4
24H2	10 % acetic acid, 24h	-0.73	52.8
25H1	10 % acetic acid, 24h	-0.61	54.2
28H3	10 % acetic acid, 24h	-0.49	60.3
30H3	10 % acetic acid, 24h	-0.60	65.7
31H1	10 % acetic acid, 24h	-0.57	67.1
33H2	10 % acetic acid, 24h replicate[a]	-0.42	71.4
35H3	10 % acetic acid, 24h	-0.27	78.8
36H1	10 % acetic acid, 24h	-0.23	80.8
vivianite			
9H3	2M nitric acid, 24h	-0.44	23.4
9H3	2M nitric acid, 24h	-0.52	23.4
15A3	2M nitric acid, 24h	-0.61	36.7
21A1	2M nitric acid, 24h	-0.46	46.8
21A1	2M nitric acid, 24h	-0.39	46.8

reference		δ^{56}Fe	2 σ deviation
HanFe	pure Fe solution - not processed	0.31	± 0.02 (n=10)
BHVO-2	10% acet. acid/24h, then HF/HNO_3	-0.12	± 0.01 (n=2)
COQ-1	10% acet. acid/24h, then HF/HNO_3	-0.05	± 0.04 (n=2)
COQ-1	6M HCl/24h, then HF/HNO_3	-0.02	± 0.04 (n=4)
COQ-1	HCl/HF/HNO_3 total digestion	-0.04	± 0.04 (n=4)

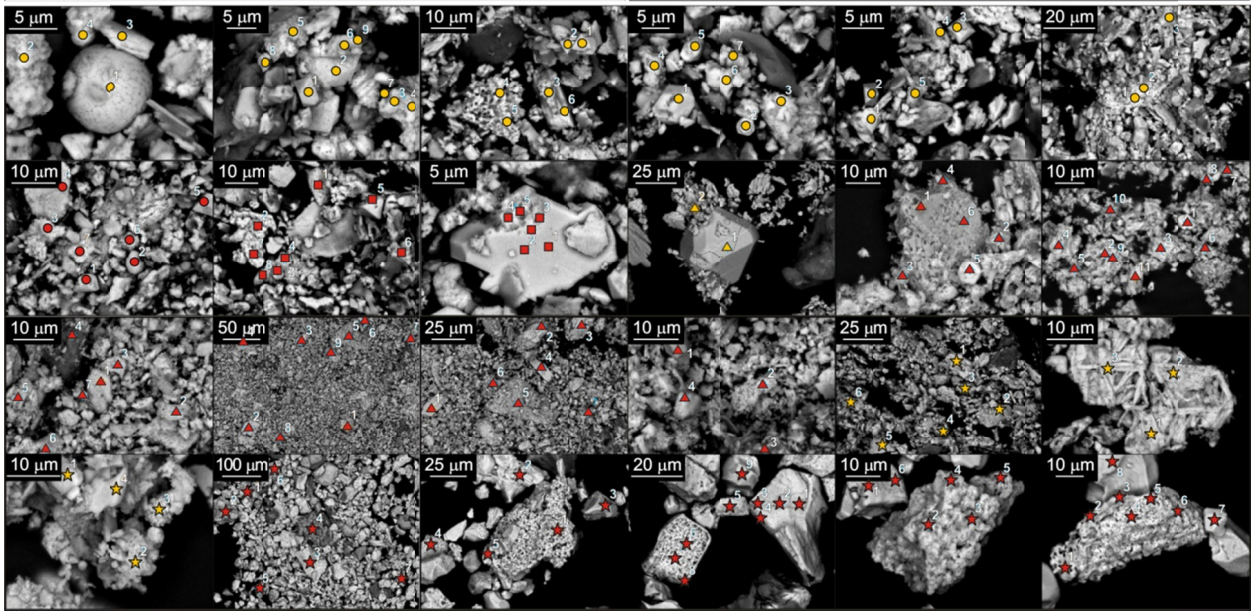
literature		δ^{56}Fe	
HanFe	pure Fe solution - not processed	0.29	Moeller et al. (2014)
COQ-1	total digestion	-0.12	Craddock and Dauphas (2011)
COQ-1	total digestion	0.00	Dideriksen et al. (2006)
COQ-1	total digestion	0.07	Dideriksen et al. (2006)
COQ-1	total digestion	-0.07	He et al. (2015)
BHVO-2	total digestion	0.11	Craddock and Dauphas (2011)

The uncertainty in the Fe isotope data is 0.05 ‰ (2 σ, δ^{56}Fe).

[a]Full procedure replicate incl. sample dissolution of a different crystal (vivianite), Fe column chemistry purification and measurement by MC-ICP-MS.

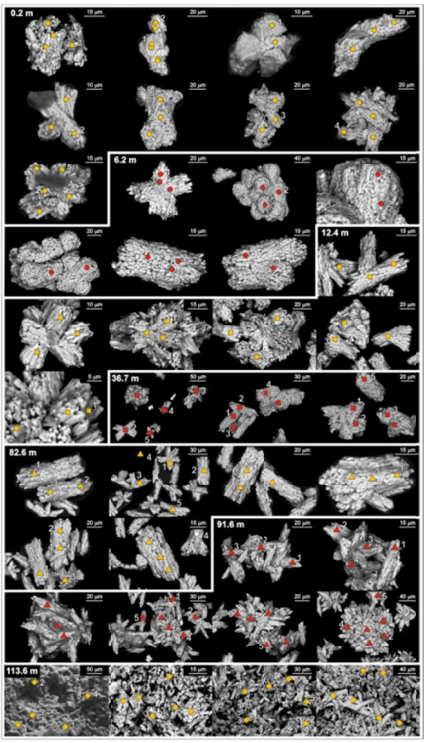
Supplementary Table S3. Results of EDS analyses on magnetic extracts and corresponding SEM images. Potential authigenic magnetites are signified by values in red font.

Depth [mblf]	Sample	O [atomic %]	Fe [atomic %]	Mn [atomic %]	Ni [atomic %]	Cr+Ti [atomic %]	V,Cu,Zn,Mo [atomic %]	Trace metal Mn [%]
0.16	Crystal 1 pt.1	70.82	28.73	0.31	0.14	0.00	0.00	68.88
0.16	Crystal 1 pt.2	75.37	23.62	0.79	0.15	0.06	0.00	78.90
0.16	Crystal 1 pt.3	74.61	25.17	0.00	0.17	0.05	0.00	0.00
0.16	Crystal 1 pt.4	63.56	35.43	0.38	0.63	0.00	0.00	37.60
0.16	Crystal 3 pt.1	68.43	30.98	0.54	0.00	0.05	0.00	92.28
0.16	Crystal 3 pt.2	62.73	36.01	0.79	0.39	0.08	0.00	62.97
0.16	Crystal 3 pt.3	74.92	24.32	0.70	0.00	0.05	0.00	93.03
0.16	Crystal 3 pt.4	73.16	25.98	0.74	0.08	0.04	0.00	86.47
0.16	Crystal 3 pt.5	81.13	18.18	0.39	0.23	0.07	0.00	56.49
0.16	Crystal 3 pt.6	80.52	18.70	0.15	0.24	0.33	0.06	18.93
0.16	Crystal 3 pt.7	74.20	25.37	0.22	0.14	0.07	0.00	50.76
0.16	Crystal 3 pt.8	79.88	18.98	0.14	0.00	1.00	0.00	12.06
0.16	Crystal 3 pt.9	74.74	22.95	0.43	1.59	0.30	0.00	18.48
0.16	Crystal 4 pt.1	63.90	35.38	0.27	0.33	0.11	0.00	38.31
0.16	Crystal 4 pt.2	70.23	28.85	0.24	0.40	0.15	0.14	25.49
0.16	Crystal 4 pt.3	71.92	27.11	0.51	0.41	0.05	0.00	52.73
0.16	Crystal 4 pt.4	82.65	16.73	0.33	0.20	0.08	0.00	54.23
0.16	Crystal 4 pt.5	80.84	18.59	0.26	0.31	0.00	0.00	45.49
0.16	Crystal 4 pt.6	65.56	34.08	0.00	0.00	0.24	0.12	0.00
0.16	Crystal 5 pt.1	74.07	23.93	0.57	1.40	0.03	0.00	28.57
0.16	Crystal 5 pt.2	71.08	24.31	0.25	0.25	4.03	0.09	5.35
0.16	Crystal 5 pt.3	79.84	19.51	0.43	0.16	0.05	0.00	66.46
0.16	Crystal 5 pt.4	75.14	24.26	0.20	0.29	0.11	0.00	32.94
0.16	Crystal 5 pt.5	75.55	22.12	0.21	2.11	0.00	0.00	9.22
0.16	Crystal 5 pt.6	65.51	34.49	0.00	0.00	0.00	0.00	0.00
0.16	Crystal 5 pt.7	72.64	27.20	0.16	0.00	0.00	0.00	100.00
0.16	Crystal 6 pt.1	64.36	35.32	0.32	0.00	0.00	0.00	100.00
0.16	Crystal 6 pt.2	71.95	27.30	0.37	0.32	0.07	0.00	48.89
0.16	Crystal 6 pt.3	68.96	30.19	0.59	0.20	0.06	0.00	69.78
0.16	Crystal 6 pt.4	77.38	22.27	0.21	0.10	0.04	0.00	60.50
0.16	Crystal 6 pt.5	82.98	16.72	0.25	0.00	0.06	0.00	81.96
0.16	Crystal 7 pt.1	69.17	30.43	0.23	0.00	0.17	0.00	57.88
0.16	Crystal 7 pt.2	61.67	37.80	0.39	0.00	0.14	0.00	73.54
0.16	Crystal 7 pt.3	80.06	19.20	0.40	0.30	0.04	0.00	54.38
6.25	Crystal 2 pt.1	71.50	27.93	0.56	0.00	0.00	0.00	100.00
6.25	Crystal 2 pt.2	72.01	26.99	0.21	0.41	0.39	0.00	20.60
6.25	Crystal 2 pt.3	75.28	24.21	0.20	0.31	0.00	0.00	39.32
6.25	Crystal 2 pt.4	72.13	27.07	0.52	0.15	0.13	0.00	65.31
6.25	Crystal 2 pt.5	67.94	30.54	0.57	0.79	0.16	0.00	37.52
6.25	Crystal 2 pt.6	70.92	27.43	0.51	0.81	0.26	0.07	30.70
6.25	Crystal 2 pt.7	75.45	23.79	0.51	0.21	0.04	0.00	66.57
12.35	Crystal 2 pt.1	75.84	23.53	0.63	0.00	0.00	0.00	100.00
12.35	Crystal 2 pt.2	86.76	12.52	0.39	0.33	0.00	0.00	53.85
12.35	Crystal 2 pt.3	82.17	17.51	0.32	0.00	0.00	0.00	100.00
12.35	Crystal 2 pt.4	66.23	33.22	0.55	0.00	0.00	0.00	100.00
12.35	Crystal 2 pt.5	78.74	20.64	0.46	0.16	0.00	0.00	74.66
12.35	Crystal 2 pt.6	76.28	23.00	0.36	0.37	0.00	0.00	49.13
12.35	Crystal 2 pt.7	76.74	22.52	0.54	0.19	0.00	0.00	73.53
12.35	Crystal 2 pt.8	80.91	18.68	0.29	0.00	0.00	0.12	69.82
12.35	Crystal 7 pt.1	70.49	28.85	0.52	0.14	0.00	0.00	78.38
12.35	Crystal 7 pt.2	70.74	28.22	0.60	0.40	0.04	0.00	57.43
12.35	Crystal 7 pt.3	72.88	25.54	0.49	0.99	0.10	0.00	31.14
12.35	Crystal 7 pt.4	70.18	28.69	0.49	0.60	0.05	0.00	43.04
12.35	Crystal 7 pt.5	72.25	26.77	0.51	0.47	0.00	0.00	51.93
12.35	Crystal 7 pt.6	64.43	33.76	0.75	0.92	0.14	0.00	41.17
36.74	Crystal 1 pt.1	72.86	24.06	0.31	0.00	2.67	0.11	10.00
36.74	Crystal 1 pt.2	84.51	15.04	0.22	0.16	0.07	0.00	47.99
82.6	Crystal 1 pt.1	82.78	8.08	0.14	0.00	8.96	0.05	1.51
82.6	Crystal 1 pt.2	69.93	29.35	0.12	0.00	0.60	0.00	17.31
82.6	Crystal 1 pt.3	77.50	20.95	0.18	0.45	0.92	0.00	11.47
82.6	Crystal 1 pt.4	83.43	13.10	0.18	0.00	3.24	0.05	5.09
82.6	Crystal 1 pt.5	67.42	31.95	0.00	0.11	0.52	0.00	0.00
82.6	Crystal 1 pt.6	74.62	12.15	0.22	0.00	12.95	0.06	1.67
82.6	Crystal 2 pt.1	70.86	27.44	0.00	0.11	1.45	0.14	0.00
82.6	Crystal 2 pt.2	74.77	24.77	0.26	0.14	0.06	0.00	56.33
82.6	Crystal 2 pt.3	72.54	27.42	0.00	0.00	0.04	0.00	0.00
82.6	Crystal 2 pt.4	72.27	26.78	0.55	0.32	0.09	0.00	57.52
82.6	Crystal 2 pt.5	83.49	16.03	0.39	0.03	0.06	0.00	80.81
82.6	Crystal 2 pt.6	85.68	13.53	0.13	0.06	0.60	0.00	16.13
82.6	Crystal 2 pt.7	74.70	24.83	0.00	0.00	0.47	0.00	0.00
82.6	Crystal 2 pt.8	74.47	25.38	0.00	0.07	0.08	0.00	0.00
82.6	Crystal 2 pt.9	80.77	19.06	0.00	0.00	0.17	0.00	0.00
82.6	Crystal 2 pt.10	85.48	14.22	0.08	0.10	0.12	0.00	26.71
82.6	Crystal 2 pt.11	88.26	11.17	0.22	0.15	0.21	0.00	37.60
82.6	Crystal 3 pt.1	76.06	23.15	0.31	0.39	0.09	0.00	39.93
82.6	Crystal 3 pt.2	79.58	20.00	0.17	0.19	0.05	0.00	41.70
82.6	Crystal 3 pt.3	74.62	24.65	0.40	0.24	0.09	0.00	54.72
82.6	Crystal 3 pt.4	95.15	4.58	0.00	0.10	0.17	0.00	0.00
82.6	Crystal 3 pt.5	76.97	22.22	0.27	0.39	0.14	0.00	33.59
82.6	Crystal 3 pt.6	76.18	23.77	0.00	0.00	0.05	0.00	0.00
82.6	Crystal 3 pt.7	74.26	19.10	0.25	0.10	6.09	0.21	3.73
82.6	Crystal 4 pt.1	77.02	22.76	0.00	0.00	0.19	0.02	0.00
82.6	Crystal 4 pt.2	72.96	26.43	0.44	0.10	0.07	0.00	72.79
82.6	Crystal 4 pt.3	72.96	26.90	0.00	0.00	0.14	0.00	0.00
82.6	Crystal 4 pt.4	72.03	27.88	0.00	0.00	0.08	0.00	0.00
82.6	Crystal 4 pt.5	77.61	12.27	0.20	0.00	9.83	0.09	1.94
82.6	Crystal 4 pt.6	62.90	36.77	0.00	0.00	0.19	0.14	0.00
82.6	Crystal 4 pt.7	75.27	24.39	0.20	0.09	0.05	0.00	57.27
82.6	Crystal 4 pt.8	73.54	26.34	0.00	0.03	0.09	0.00	0.00
82.6	Crystal 4 pt.9	72.14	27.64	0.00	0.00	0.21	0.00	0.00
82.6	Crystal 5 pt.1	73.57	26.27	0.00	0.00	0.15	0.00	0.00
82.6	Crystal 5 pt.2	72.39	27.30	0.15	0.00	0.12	0.04	48.78
82.6	Crystal 5 pt.3	76.10	23.81	0.00	0.00	0.09	0.00	0.00
82.6	Crystal 5 pt.4	61.16	38.44	0.00	0.00	0.25	0.14	0.00
82.6	Crystal 5 pt.5	76.70	15.65	0.15	0.00	7.45	0.05	2.00
82.6	Crystal 5 pt.6	68.98	30.20	0.15	0.22	0.44	0.00	18.85
82.6	Crystal 5 pt.7	74.73	24.52	0.24	0.21	0.23	0.06	32.70
82.6	Crystal 6 pt.1	66.10	33.65	0.00	0.14	0.10	0.00	0.00
82.6	Crystal 6 pt.2	71.11	28.27	0.22	0.28	0.11	0.00	35.86
82.6	Crystal 6 pt.3	90.40	9.11	0.00	0.16	0.33	0.00	0.00
82.6	Crystal 6 pt.4	62.99	36.61	0.00	0.31	0.09	0.00	0.00
91.57	Crystal 1 pt.1	74.17	25.03	0.49	0.23	0.08	0.00	61.68
91.57	Crystal 1 pt.2	72.30	24.51	0.00	0.19	2.95	0.06	0.00
91.57	Crystal 1 pt.3	75.48	23.68	0.57	0.15	0.12	0.00	67.63
91.57	Crystal 1 pt.4	73.95	25.36	0.16	0.20	0.22	0.00	23.54
91.57	Crystal 1 pt.5	65.69	33.15	0.54	0.41	0.13	0.07	46.87
91.57	Crystal 1 pt.6	74.14	24.83	0.51	0.42	0.10	0.00	49.60
91.57	Crystal 3 pt.1	74.80	24.98	0.00	0.00	0.22	0.00	0.00
91.57	Crystal 3 pt.2	75.51	24.15	0.00	0.00	0.28	0.06	0.00
91.57	Crystal 3 pt.3	74.31	24.21	0.00	0.00	1.49	0.00	0.00
91.57	Crystal 8 pt.1	64.59	34.47	0.69	0.16	0.09	0.00	73.78
91.57	Crystal 8 pt.2	80.23	19.52	0.14	0.12	0.00	0.00	54.47
91.57	Crystal 8 pt.3	76.05	23.31	0.48	0.00	0.07	0.09	75.40
91.57	Crystal 8 pt.4	73.71	24.72	0.00	0.09	1.27	0.11	0.00
113.58	Crystal 1 pt.1	75.54	22.22	0.28	0.00	1.85	0.11	12.72
113.58	Crystal 1 pt.2	73.43	26.05	0.25	0.00	0.27	0.00	47.59
113.58	Crystal 1 pt.3	73.72	25.53	0.25	0.00	0.36	0.15	33.03
113.58	Crystal 1 pt.4	75.68	23.40	0.61	0.00	0.32	0.00	65.63
113.58	Crystal 1 pt.5	73.04	15.55	0.42	0.00	10.35	0.13	3.71
113.58	Crystal 1 pt.6	73.89	14.57	0.69	0.00	10.35	0.30	5.99
113.58	Crystal 1 pt.7	70.35	20.06	0.90	0.00	8.40	0.29	9.39
113.58	Crystal 3 pt.1	74.96	24.80	0.00	0.00	0.24	0.00	0.00
113.58	Crystal 3 pt.2	74.56	21.04	0.00	0.00	4.22	0.18	0.00
113.58	Crystal 3 pt.3	73.96	15.25	0.26	0.00	10.35	0.18	2.43
113.58	Crystal 3 pt.4	76.15	15.78	0.46	0.10	7.41	0.09	5.69
113.58	Crystal 3 pt.5	72.25	25.71	0.00	0.27	1.77	0.00	0.00
113.58	Crystal 4 pt.1	74.97	22.70	0.00	0.22	2.05	0.06	0.00
113.58	Crystal 4 pt.2	73.17	24.58	0.00	0.24	1.96	0.05	0.00
113.58	Crystal 4 pt.3	69.15	28.37	0.00	0.25	2.15	0.08	0.00
113.58	Crystal 4 pt.4	76.14	21.97	0.00	0.22	1.62	0.06	0.00
113.58	Crystal 4 pt.5	73.67	22.69	0.00	0.11	3.42	0.11	0.00
113.58	Crystal 4 pt.6	61.39	30.55	0.74	0.00	6.88	0.44	9.22
113.58	Crystal 4 pt.7	70.46	24.30	0.51	0.00	4.67	0.06	9.68
113.58	Crystal 4 pt.8	81.99	15.79	0.17	0.05	1.96	0.04	7.65
113.58	Crystal 4 pt.9	71.45	19.70	0.00	0.16	8.53	0.15	0.00
113.58	Crystal 5 pt.1	74.45	23.21	0.00	0.26	2.09	0.00	0.00
113.58	Crystal 5 pt.2	77.12	22.72	0.00	0.00	0.16	0.00	0.00
113.58	Crystal 5 pt.3	81.73	17.90	0.13	0.00	0.19	0.06	35.40
113.58	Crystal 5 pt.4	81.27	18.36	0.00	0.00	0.27	0.10	0.00
113.58	Crystal 5 pt.5	78.56	21.22	0.00	0.00	0.20	0.01	0.00
113.58	Crystal 5 pt.6	64.20	32.74	0.00	0.33	2.67	0.07	0.00
113.58	Crystal 6 pt.1	80.37	17.88	0.00	0.00	1.52	0.23	0.00
113.58	Crystal 6 pt.2	68.19	29.23	0.00	0.00	2.26	0.32	0.00
113.58	Crystal 6 pt.3	69.50	27.76	0.00	0.00	2.28	0.37	0.00
113.58	Crystal 6 pt.4	72.53	25.52	0.00	0.00	1.56	0.39	0.00
113.58	Crystal 6 pt.5	69.59	28.28	0.00	0.00	1.13	0.40	0.00
113.58	Crystal 6 pt.6	67.88	29.99	0.00	0.00	1.70	0.43	0.00
113.58	Crystal 6 pt.7	72.62	23.93	0.00	0.19	3.20	0.06	0.00
113.58	Crystal 6 pt.8	75.81	16.23	0.50	0.00	7.16	0.30	6.25



Supplementary Table S4. Results of EDS analyses on siderite samples and corresponding SEM images.

Depth [mblf]	Sample	Mg [atomic %]	Ca [atomic %]	Mn [atomic %]	Fe [atomic %]	O [atomic %]
0.16	Crystal 1	1.60	0.43	0.59	20.53	43.97
0.16	Crystal 1	1.75	0.41	0.84	23.55	40.98
0.16	Crystal 1	5.81	0.51	0.45	17.12	46.90
0.16	Crystal 1	0.44	0.55	0.86	22.54	41.68
0.16	Crystal 2	1.28	0.23	0.27	11.73	64.70
0.16	Crystal 2	0.35	0.20	0.43	4.31	84.23
0.16	Crystal 2	4.26	0.31	0.21	8.87	70.12
0.16	Crystal 2	1.09	0.32	0.51	15.97	57.57
0.16	Crystal 3	0.29	0.15	3.26	7.66	67.44
0.16	Crystal 3	0.35	0.22	3.53	11.31	58.16
0.16	Crystal 3	0.76	0.20	4.11	11.11	57.65
0.16	Crystal 3	0.40	0.33	6.10	19.47	39.06
0.16	Crystal 3	0.58	0.38	7.71	17.83	38.67
0.16	Crystal 3	1.24	0.33	6.42	18.11	39.91
0.16	Crystal 6	1.81	0.14	0.71	16.98	55.68
0.16	Crystal 6	2.69	0.16	0.62	13.72	60.98
0.16	Crystal 7	1.26	0.36	1.02	13.27	60.82
0.16	Crystal 7	1.86	0.35	0.93	14.50	58.20
0.16	Crystal 7	1.40	0.33	0.77	11.04	65.52
0.16	Crystal 8	0.34	0.23	3.73	12.43	56.63
0.16	Crystal 8	0.55	0.21	3.54	12.65	55.58
0.16	Crystal 8	1.46	0.20	3.78	9.72	59.19
0.16	Crystal 9	0.14	0.12	1.64	18.19	51.82
0.16	Crystal 9	0.29	0.10	1.22	16.35	55.10
0.16	Crystal 9	0.24	0.09	1.45	14.80	57.53
0.16	Crystal 10	0.70	0.20	0.35	16.10	58.74
0.16	Crystal 10	0.56	0.25	0.49	17.53	55.72
0.16	Crystal 10	0.77	0.26	0.30	15.27	60.37
0.16	Crystal 11	0.79	0.29	0.27	13.72	65.12
0.16	Crystal 11	0.04	0.25	0.74	24.98	40.52
0.16	Crystal 11	0.21	0.37	1.65	22.20	43.97
0.16	Crystal 11	1.63	0.72	0.13	18.17	53.37
0.16	Crystal 12	0.10	0.16	6.16	19.48	40.08
0.16	Crystal 12	0.44	0.21	3.92	7.76	67.86
0.16	Crystal 12	0.15	0.26	5.66	10.56	55.84
0.16	Crystal 12	0.62	0.20	3.58	7.00	64.72
0.16	Crystal 12	0.77	0.20	3.36	6.50	66.51
6.25	Crystal 1	3.22	0.55	1.44	20.76	42.60
6.25	Crystal 1	3.16	0.60	1.63	20.82	42.37
6.25	Crystal 1	18.72	0.08	0.00	3.14	58.51
6.25	Crystal 2	1.36	0.30	0.74	12.83	62.61
6.25	Crystal 2	13.72	0.07	0.05	2.28	66.28
6.25	Crystal 5	1.94	0.64	1.62	22.14	41.03
6.25	Crystal 5	0.96	0.56	1.71	23.27	40.28
6.25	Crystal 5	2.58	0.69	1.52	21.09	41.36
6.25	Crystal 6	1.69	0.55	1.16	22.23	40.71
6.25	Crystal 6	2.66	0.65	1.34	21.84	41.76
6.25	Crystal 8	2.26	0.69	1.38	22.22	41.35
6.25	Crystal 8	1.84	0.69	1.37	22.69	41.00
6.25	Crystal 9	2.33	0.76	1.84	22.11	40.82
6.25	Crystal 9	2.19	0.55	1.08	22.37	41.71
6.25	Crystal 9	1.88	0.58	1.47	22.32	41.33
6.25	Crystal 10	2.88	0.66	1.56	21.59	41.63
6.25	Crystal 10	2.33	0.68	1.95	22.14	40.70
12.35	Crystal 2	1.41	0.31	6.95	17.11	38.63
12.35	Crystal 2	0.60	0.27	5.66	19.44	39.43
12.35	Crystal 2	1.51	0.33	7.94	16.72	39.38
12.35	Crystal 5	1.18	0.40	7.55	17.57	38.97
12.35	Crystal 5	1.75	0.35	7.16	16.99	39.99
12.35	Crystal 5	1.61	0.34	7.50	16.97	39.62
12.35	Crystal 8	1.69	0.30	5.79	18.49	40.20
12.35	Crystal 8	1.54	0.25	5.43	18.59	40.64
12.35	Crystal 8	2.01	0.24	5.58	18.33	40.60
12.35	Crystal 10	0.64	0.36	6.89	18.43	39.07
12.35	Crystal 10	1.89	0.39	7.63	16.08	40.34
12.35	Crystal 10	0.48	0.34	6.69	19.00	38.77
12.35	Crystal 11	0.81	0.30	5.19	20.19	39.35
12.35	Crystal 11	0.80	0.30	5.56	19.70	39.39
12.35	Crystal 11	0.77	0.29	5.78	19.34	39.55
12.35	Crystal 13	0.69	0.13	2.25	5.14	75.53
12.35	Crystal 13	1.44	0.31	7.56	17.34	39.21
12.35	Crystal 13	0.97	0.36	8.88	16.55	38.45
36.74	Crystal 4	0.00	0.16	2.34	12.34	61.32
36.74	Crystal 4	0.00	0.15	2.52	11.46	62.45
36.74	Crystal 4	0.21	0.22	1.14	10.44	67.16
36.74	Crystal 4	0.00	0.21	1.14	11.97	66.75
36.74	Crystal 4	0.21	0.13	1.22	10.83	68.29
36.74	Crystal 4	0.00	0.00	0.08	19.59	53.84
36.74	Crystal 6	0.00	0.23	1.46	13.85	61.60
36.74	Crystal 6	0.24	0.20	1.24	11.85	65.06
36.74	Crystal 6	0.29	0.17	0.88	8.84	70.98
36.74	Crystal 6	0.30	0.17	1.09	15.28	58.51
36.74	Crystal 6	0.33	0.09	0.96	13.44	62.79
36.74	Crystal 6	0.38	0.08	0.60	8.79	74.85
36.74	Crystal 6	0.00	0.22	1.23	12.35	63.74
36.74	Crystal 6	0.00	0.22	1.29	12.38	63.94
36.74	Crystal 6	0.24	0.18	1.39	14.63	59.51
36.74	Crystal 6	0.31	0.19	2.11	13.46	59.93
82.6	Crystal 2	0.51	0.09	0.26	11.07	71.23
82.6	Crystal 2	3.17	0.00	0.00	4.52	75.98
82.6	Crystal 2	0.53	0.12	0.39	11.69	67.45
82.6	Crystal 3	0.35	0.12	1.00	13.86	62.06
82.6	Crystal 3	0.49	0.14	0.52	13.03	65.06
82.6	Crystal 3	0.55	0.17	0.99	13.55	61.69
82.6	Crystal 3	0.53	0.15	0.54	13.75	64.48
82.6	Crystal 3	0.33	0.10	0.96	13.44	62.90
82.6	Crystal 4	0.51	0.15	1.01	15.46	58.27
82.6	Crystal 4	0.64	0.18	0.53	15.91	58.58
82.6	Crystal 4	0.46	0.10	0.57	12.50	67.28
82.6	Crystal 7	0.46	0.09	0.19	10.14	73.30
82.6	Crystal 7	0.46	0.10	0.86	12.96	63.91
82.6	Crystal 7	0.59	0.12	0.56	12.91	63.50
82.6	Crystal 8	0.65	0.13	0.43	12.36	65.41
82.6	Crystal 8	0.24	0.13	0.92	18.30	54.00
82.6	Crystal 8	1.01	0.31	0.14	10.79	71.00
82.6	Crystal 8	0.70	0.17	0.38	14.50	61.57
82.6	Crystal 12	0.33	0.13	1.20	15.02	59.99
82.6	Crystal 12	0.43	0.13	1.02	15.23	59.40
82.6	Crystal 12	2.14	0.19	0.28	12.24	64.03
82.6	Crystal 12	0.48	0.13	0.60	14.09	62.98
91.57	Crystal 2	1.36	0.45	0.36	13.64	62.18
91.57	Crystal 2	1.14	0.35	0.58	11.35	65.96
91.57	Crystal 2	0.82	0.29	1.05	11.86	63.63
91.57	Crystal 4	2.48	0.41	0.55	12.41	61.56
91.57	Crystal 4	1.05	0.40	0.74	14.42	59.14
91.57	Crystal 4	1.22	0.45	0.30	12.21	64.75
91.57	Crystal 4	1.44	0.45	0.16	9.39	72.48
91.57	Crystal 5	1.10	0.38	0.83	14.90	58.43
91.57	Crystal 5	0.88	0.32	0.71	13.43	61.53
91.57	Crystal 5	1.80	0.16	0.08	3.41	76.06
91.57	Crystal 6	1.09	0.29	0.60	12.13	64.46
91.57	Crystal 6	1.50	0.51	0.34	13.87	61.42
91.57	Crystal 6	1.12	0.37	0.56	12.81	61.48
91.57	Crystal 6	0.95	0.36	1.07	14.72	57.75
91.57	Crystal 6	0.73	0.30	1.13	15.03	58.23
91.57	Crystal 6	0.99	0.41	0.78	12.71	63.83
91.57	Crystal 8	0.10	0.03	0.03	0.63	76.36
91.57	Crystal 8	2.63	0.36	0.24	13.05	63.49
91.57	Crystal 8	0.49	0.25	1.06	11.60	61.66
91.57	Crystal 8	0.96	0.44	0.44	13.50	61.73
91.57	Crystal 8	1.18	0.46	0.49	14.29	60.60
91.57	Crystal 9	1.08	0.37	0.59	14.07	61.30
91.57	Crystal 9	0.00	0.24	2.05	11.93	60.86
91.57	Crystal 9	1.05	0.33	0.66	13.20	62.42
91.57	Crystal 9	0.54	0.33	0.80	14.49	60.19
91.57	Crystal 9	1.05	0.33	1.15	14.71	58.80
91.57	Crystal 9	0.22	0.16	2.95	14.65	55.61
113.58	Crystal 2	0.00	0.10	1.73	12.71	62.57
113.58	Crystal 2	0.00	0.14	0.64	13.59	63.65
113.58	Crystal 2	0.30	0.17	2.32	12.72	59.11
113.58	Crystal 2	0.17	0.19	2.13	14.54	57.41
113.58	Crystal 2	0.00	0.17	0.60	15.35	60.16
113.58	Crystal 5	2.91	0.58	0.13	12.30	66.41
113.58	Crystal 5	1.84	0.39	0.12	12.22	67.73
113.58	Crystal 5	3.07	0.70	0.15	11.85	66.92
113.58	Crystal 5	0.99	0.29	0.37	15.19	60.03
113.58	Crystal 5	1.63	0.37	0.16	11.57	69.22
113.58	Crystal 5	3.26	0.71	0.22	11.22	67.89
113.58	Crystal 7	0.48	0.20	1.02	17.90	54.03
113.58	Crystal 7	1.00	0.34	0.30	15.77	58.67
113.58	Crystal 7	1.22	0.22	0.42	11.64	66.88
113.58	Crystal 7	0.92	0.20	0.41	10.51	71.72
113.58	Crystal 7	0.61	0.23	0.53	15.16	59.99
113.58	Crystal 7	0.13	0.17	3.05	14.45	55.01
113.58	Crystal 9	0.16	0.26	0.68	16.65	56.47
113.58	Crystal 9	0.00	0.15	2.17	14.91	56.69
113.58	Crystal 9	0.00	0.21	1.05	14.46	60.28
113.58	Crystal 9	0.94	0.30	0.25	14.94	60.88
113.58	Crystal 9	1.13	0.19	0.61	9.78	66.23
113.58	Crystal 9	1.44	0.57	0.26	15.41	59.00



Supplementary Table S5. Results of EDS analyses on vivianite samples and corresponding SEM images.

Depth [mblf]	Sample	P [atomic %]	Mn [atomic %]	Fe [atomic %]	O [atomic %]
23.36	Crystal 3	6.11	1.60	6.81	67.09
23.36	Crystal 3	6.25	1.38	6.73	68.99
23.36	Crystal 3	7.22	2.28	8.11	63.93
23.36	Crystal 4	6.65	2.22	7.93	65.63
23.36	Crystal 4	7.28	2.75	8.66	62.70
23.36	Crystal 4	5.88	2.38	9.32	64.13
23.36	Crystal 4	6.71	2.08	8.29	64.83
23.36	Crystal 5	6.75	1.75	8.40	64.87
23.36	Crystal 5	6.68	1.38	8.42	65.59
23.36	Crystal 5	6.51	1.40	7.31	67.40
23.36	Crystal 6	7.59	3.14	8.20	63.73
23.36	Crystal 6	6.47	1.63	7.94	63.93
23.36	Crystal 6	4.82	1.34	5.33	63.75
23.36	Crystal 6	6.06	0.72	7.11	64.51
23.36	Crystal 8	6.64	1.81	6.98	63.76
23.36	Crystal 8	7.41	1.85	9.47	64.14
23.36	Crystal 8	6.63	1.24	8.90	64.12
23.36	Crystal 9	3.02	1.61	5.80	65.36
23.36	Crystal 9	5.45	1.76	7.87	64.30
23.36	Crystal 11	6.68	1.81	7.36	63.45
23.36	Crystal 11	7.67	2.56	8.22	63.30
23.36	Crystal 11	6.26	1.73	6.89	63.60
23.36	Crystal 12	7.96	2.33	8.35	63.73
23.36	Crystal 12	7.85	2.21	8.47	63.24
23.36	Crystal 12	6.63	2.21	8.34	64.25
23.36	Crystal 12	8.48	2.47	10.17	64.70
36.74	Crystal 1	7.02	2.11	8.49	63.65
36.74	Crystal 1	6.50	2.94	11.70	64.20
36.74	Crystal 1	6.82	1.94	7.58	63.22
36.74	Crystal 1	6.52	1.34	7.26	63.79
36.74	Crystal 1	6.42	1.67	7.24	63.57
36.74	Crystal 1	6.07	1.68	7.14	63.93
36.74	Crystal 1	7.41	1.79	10.26	63.80
36.74	Crystal 3	6.40	3.15	10.23	63.44
36.74	Crystal 3	7.76	2.38	7.99	63.16
36.74	Crystal 3	0.50	1.73	10.76	64.24
36.74	Crystal 3	6.50	1.80	11.46	64.02
36.74	Crystal 3	6.45	1.61	7.58	63.79

Depth [mblf]	Sample	P [atomic %]	Mn [atomic %]	Fe [atomic %]	O [atomic %]
36.74	Crystal 3	7.94	2.18	8.14	62.80
36.74	Crystal 3	3.11	0.70	3.50	65.20
36.74	Crystal 3	0.47	5.12	33.00	59.53
36.74	Crystal 3	6.88	2.29	14.26	63.85
36.74	Crystal 3	0.45	4.14	33.54	59.72
36.74	Crystal 3	4.68	2.81	22.25	62.56
36.74	Crystal 3	2.19	4.09	28.87	60.81
36.74	Crystal 3	1.24	2.75	17.23	62.71
36.74	Crystal 4	7.39	1.61	8.61	63.62
36.74	Crystal 4	7.75	2.30	9.41	63.94
36.74	Crystal 4	6.20	2.98	15.94	63.90
36.74	Crystal 4	8.59	3.12	9.60	63.17
36.74	Crystal 4	7.00	2.49	13.61	64.15
36.74	Crystal 6	3.57	2.22	7.36	64.35
36.74	Crystal 6	7.03	2.79	9.16	64.28
36.74	Crystal 6	6.59	2.31	9.78	64.23
36.74	Crystal 7	7.23	1.59	9.49	64.10
36.74	Crystal 7	6.72	1.82	9.72	64.03
36.74	Crystal 7	7.80	2.55	11.32	62.88
36.74	Crystal 8	7.80	1.67	9.12	63.55
36.74	Crystal 8	4.57	3.59	19.93	62.62
36.74	Crystal 8	7.25	1.70	8.12	63.56
36.74	Crystal 8	7.75	2.01	10.20	64.04
36.74	Crystal 10	7.30	1.36	8.87	64.00
36.74	Crystal 10	8.29	2.33	9.98	63.81
36.74	Crystal 10	7.35	1.90	10.68	64.28
36.74	Crystal 10	8.14	1.72	11.13	64.10
36.74	Crystal 10	8.50	2.58	10.24	64.46
36.74	Crystal 10	8.11	2.60	10.13	63.98
36.74	Crystal 12	7.90	2.43	11.90	63.75
36.74	Crystal 12	7.10	2.14	7.65	63.08
36.74	Crystal 16	5.39	1.36	6.42	64.22
36.74	Crystal 16	7.23	2.03	11.54	63.94
36.74	Crystal 16	7.81	3.16	11.84	63.29
46.83	Crystal 1	4.99	0.32	7.06	65.90
46.83	Crystal 2	5.95	0.48	7.98	65.21
46.83	Crystal 2	5.09	0.35	7.03	65.45
46.83	Crystal 2	5.56	0.37	7.33	65.47